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STABILITY OF 40MM SHELL MARK II T/L/.

by

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ABSTRACT

The stability factor of the 40 mm Shell Mark II T/L/, fired from a gun with a twist of rifling of 1/30, is 1.48 at a velocity of 2890 ft/sec, and 1.23 at 1200 ft/sec.

LIST OF TABLES

1. AUTHORITY: These firings constituted part of the proof test of the 40 mm Bofors Guns, authorized by letter from the Chief of Ordnance, OO 472.93/2642 (APG 472/383).

2. OBJECT: The specific object of this part of the test was to determine the stability factor of the Shell Mark II T/L/.

3. GUN: 40 mm Bofors Gun, mounted on its own carriage, containing tube No. 1 which was rifled with a twist of 1 turn in 30 calibers. Tube No. 2, rifled 1/25, was being proof tested under the same program, but was not used for the stability test because the small yaws obtainable with this tube would not provide accurate data.

4. <u>AMMUNITION</u>:

<u>a</u>. Shell, 40 mm, Mark II T/L/, inert loaded (Drg. 75-2-298). A wooden plug was inserted in the tracer cavity, but came out when the shell was fired; in most cases, it pierced one or more yaw screens. Since the first two rounds had maximum yaws of only 3° or 4°, the bourrelets of the remaining shell were machined off to a diameter of about 1.537 inches. The unmodified bourrelet has a diameter of 1.567 - .006 in. and extended clear back to the rotating band. Behind the band, the diameter is 1.547 - .006 in. The shell has an 8° boat-tail, and a 7.5° taper in front.

<u>b</u>. Fuze, P.D., T34, inert. This fuze is 2 in. long and has a 0.3 in. meplat.

<u>c</u>. Powder, D.P. Lot X-3661-S-30 for 75 mm Gun M1897. The first two rounds were complete rounds, which contained 10.93 oz. and were fired as received. This charge was supposed to give a muzzle velocity of 2850 ft/sec, but had actually been producing more than 2900 ft/sec. The remaining rounds were disassembled and, after the shell were modified, reassembled. In 8 of these, the weight of the powder was the same as it was before they were disassembled (new charges were weighed). The last 10 rounds were assembled with charges of 2.66 oz; the velocities obtained from three additional rounds with reduced charges indicated that this charge should give about 1200 ft/sec.

5. <u>YAW SCREENS</u>: The gun was emplaced at the railway range, so that the cardboard screens could be placed in frames which had been used in previous tests. Some of these frames were permanent; others were movable. The screen distances for dense distribution are given in Table I. For sparse distribution, stations 1 to 6 and 16 to 21 were used in the high velocity firings; stations 2 to 7 and 16 to 21, in the low velocity firings.

6. <u>VELOCITY</u>: When a sparse distribution of yaw screens was used, the velocity was measured with a solenoid chronograph. The first coil was fastened to the far side of the seventh frame, and the second coil placed about 100 feet down the range. A form factor of 1.15 relative to projectile type 2 was used for correcting the velocity to the muzzle: this form factor was estimated on the basis of the height of the ogive of the shell and fuze, which is about 1.956 calibers. The average muzzle velocities obtained with the two charges are 2889 ft/sec and 1196 ft/sec.

7. FIRINGS: Five rounds were fired through dense distribution of yaw screens and five through sparse distribution at each velocity. The complete record of firings will be included with the report of the proof test, but Table II is an extract, pertaining to the stability firings.

8. JUMP: The point of boresight was marked by a cross on the first yaw screen, so that jump data could be obtained. The data and results are contained in Table III. At 2890 ft/sec, the mean jump is about 4 minutes left and 4 minutes down: at 1200 ft/sec, it is about 1 minute left, with no appreciable vertical jump.

9. DYNAMIC DATA: The five projectiles that were fired through the sparse distribution of yaw cards at the high velocity were first measured and swung. These measurements were made by the method explained in Ballistic Research Laboratory Report No. 138, "Stability of 37 mm Shell T12". The 37 mm Masses B and D were used for calibrating the torsion pendulums, but new holders and a new balance ring had to be made for the 40 mm Shell. The pendulum wires were 0.010 inch in diameter and more than 6 feet long. The balance ring was 0.253 inch wide, and the block used in measuring the center of gravity was 0.763 inch wide. The results are given in Table IV.

10. STABILITY:

a. The stability data and results are tabulated in Tables V and VI. As previously noted, the unmodified shell had maximum yaws of only 3° or 4°. Most of the modified shell, however, had large yaws, so that the results are quite well determined.

b. The average observe rate of precession is 0.032,5 semi-rev/ft. The theoretical rate, based on the twist of rifling and the average moments of inertia for five projectiles, is 0.032,28 semi-rev/ft. These are in good agreement.

c. The cardboard constants were determined by the method of least squares. The first two periods of round 15 were used for this purpose, although they were not used in determining the stability factor on account of the large cardboard correction; apparently, this shell hit a frame before it reached the end of the range, since the last maximum yaw was greater than the first (only the first is tabulated).

d. The average temperature of the air was 88.4° F. during the high velocity firings, and 87.0° F. during the low velocity firings. The corresponding velocity of sound was 1149 ft/sec and 1148 ft/sec respectively. The Mach number, defined as the ratio of the muzzle velocity to the velocity of sound, was 2.514 and 1.042 respectively.

e. At a velocity of 2890 ft/sec, the mean stability factor is 1.479 with a probable error of 0.027. At a velocity of 1200 ft/sec, the mean stability factor is only 1.229 with a probable error of 0.008.

f. At the higher velocity, the moment coefficient is 1.54 with a probable error of 0.028. At the lower velocity, it is 1.85 with a probable error of 0.012.

11. CONCLUSION: The stability factor of the 40 mm Shell Mark II T/L/, fired from a gun with a twist of rifling of 1 turn in 30 calibers, is 1.48 at a Mach number of 2.51, and 1.23 at a Mach number of 1.04. Therefore, a twist of 1/30 is quite satisfactory if the shell is fired at the standard muzzle velocity of 2850 ft/sec. But, if it were fired with a muzzle velocity near the velocity of sound when the air density is high, the twist should be steeper in order to insure ample stability.

12. ACKNOWLEDGMENTS: The assistance rendered by the following people is gratefully acknowledged: Messrs. Edw. Blaylock and E. S. Finney measured and swung the shell. Mr. W. F. Braun measured and plotted the yaw and orientation. Miss M. E. Harrington performed the computations.

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TABLE I

YAW SCREEN DISTANCES

Station No.	Distances (ft.) Between Screens	From Muzzle
1	--	27.57*
2	8.32	35.89
3	10.09	45.98
4	8.55	54.53
5	11.37	65.90
6	7.98	73.88
7	7.56	81.44
8	60.35	141.79
9	39.75	181.54
10	61.77	243.31
11	54.46	297.77
12	53.28	351.05
13	53.90	404.95
14	53.97	458.92
15	54.06	512.98
16	9.02	522.00
17	9.02	531.02
18	8.70	539.72
19	9.55	549.27
20	8.53	557.80
21	9.40	567.20

* On July 24, the distance from the muzzle to the first screen was 27.25; the distances between screens were the same as above. The tabulated distances apply to all August firings.

TABLE II

FIRING RECORD EXTRACT

Gun, 40 mm No. 1, Bofors, mfd. by Chrysler (7/24 and 8/1)
No. L-3288 Bofors, mfd. by British (8/4 and 8/5)

Tube, 40 mm No. 1, Bofors, mfd. by Otis Frensom, rifled by W'v't Ars.

Carriage, 40 mm No. 1 Bofors, mfd. by Firestone Tire and Rubber Co. (7/24 and 8/1); No. L-3288 Bofors, mfd. by British (8/4 and 8/5)

Recoil System 40 mm No. 1 Bofors, mfd. by Chrysler (7/24 and 8/1)
No. L-3288 Bofors, mfd. by British (8/4 and 8/5).

Gun Position, Railway Range, Direction of Fire, 40°.

Temp. of Powder, 70°.

Solenoid Coil Dist. (8/1) Gun to 1st, 82.53'; 1st to 2nd, 99.87'
(8/4) Gun to 1st, 82.51'; 1st to 2nd, 100.00'

Powder, D.P. Lot X-3661-S-30 for 75 mm Gun M1897

Round No.	Date 1941	Time of Firing	Powder oz.	Projectile No.	Projectile Lb.	Elev. min.	M.V. f/s
1	July 24	2:50 P.M.	10.93	--	--	-4	Not
2	July 24	3:46 P.M.	"	--	--	"	taken
3	Aug. 1	11:02 A.M.	"	6	1.92		
4	Aug. 1	11:29 A.M.	"	7	1.92	"	
5	Aug. 1	12:44 P.M.	"	8	1.94	-8	
6	Aug. 1	2:00 P.M.	"	1	1.8856	"	2872
7	Aug. 1	2:32 P.M.	"	2	1.8425	"	2868
8	Aug. 1	3:14 P.M.	"	3	1.7675	"	2904
9	Aug. 1	3:45 P.M.	"	4	1.8306	"	2914
10	Aug. 1	4:11 P.M.	"	5	1.8163	"	2888
11	Aug. 4	2:59 P.M.	2.66	9	1.94	-4	Not
12	Aug. 4	3:23 P.M.	"	10	1.94	+4	taken
13	Aug. 4	3:37 P.M.	"	11	1.93	"	
14	Aug. 4	3:47 P.M.	"	12	1.92	"	
15	Aug. 4	4:02 P.M.	"	13	1.92	"	
16	Aug. 5	9:56 A.M.	"	19	1.97	"	Lost
17	Aug. 5	10:28 A.M.	"	15	1.92	"	1218
18	Aug. 5	11:03 A.M.	"	16	1.95	"	1183
19	Aug. 5	11:12 A.M.	"	17	1.93	"	1184
20	Aug. 5	11:22 A.M.	"	18	1.93	"	1199

Remarks:
Rd. 3 Card No. 11 blew out.
Rds. 6, 7, and 11. Shell hit frame No. 15.
Proof Officer, Lt. Hamilton

TABLE III

JUMP

40 mm Bofors Gun No. 1
Shell Mk.II T/L/; P.D. Fuze T34

Round No.	X in.	Y in.
1	+.10	-.21
2	+.15	-.21
3	+.18	+.04
4	-.61	-.47
5	-.42	-.12
6	-2.05	-.30
7	-.45	-1.48
8	-.15	-1.65
9	-.27	-.72
10	-.42	-.05
11	-.18	-.24
12	-.10	-.23
13	-.08	+.54
14	-.03	-.37
15	+.05	+.36
16	-.52	-.42
17	.00	-.35
18	-.31	-.39
19	+.14	-.39
20	-.23	-.08
1-10	-.394	-.517
11-15	-.068	+.012
16-20	-.184	-.326

Round No.	M.V. f/s	Muzzle to screen ft.	Horizontal Jump (min.) mean	Horizontal Jump (min.) P.E.	Vertical Jump (min.) mean	Vertical Jump (min.) P.E.
1-10	2890	27.6	-3.7	1.21	-4.4	1.08
11-15	1200	27.6	-0.6	.23	+1.0	0.97
16-20	1200	35.9	-1.3	.55	-1.1	0.14

Elevation 0°.
Trunnions to muzzle, 9.95 ft.
X is horizontal deviation from point of boresight (pos. to right).
Y is vertical deviation from point of boresight (pos. upwards).

TABLE IV

DYNAMIC DATA

Inert 40 mm Shell Mk.II T/L/ with Wooden Tracer Plug
Fuze, P.D. T34, Inert
Bourrelet Machined Off.

Projectile No.	Weight lb.	Center of Gravity cal.	Moments of Inertia Axial $lb.in.^2$	Transverse $lb.in.^2$
1	1.8856	1.588	.6369	5.080
2	1.8425	1.568	.6293	4.937
3	1.7675	1.571	.6277	4.972
4	1.8306	1.564	.6293	4.947
5	1.8163	1.541	.6256	4.840
Average	1.8285	1.566	.6298	4.955

AVERAGE DIMENSIONS

Length	7.030 in.
Bourrelet diameter	1.537 in.
Base diameter	1.543 in.
Flat behind band	0.76 in.
Length of boat-tail	0.92 in.

TABLE V

STABILITY DATA

Inert 40 mm Shell Mk.II T/L/
Fuze, P.D. T34, Inert

Round No.	Proj. No.	Muzzle Velocity (ft/sec)	Yaw (Deg.) First Max.	Yaw (Deg.) Last Max.	Yaw (Deg.) First Min.	Yaw (Deg.) Last Min.	Min. Yaw (ft) First	Min. Yaw (ft) Last	Number of Periods	Precession (semi-rev/ft)
		M.V.	α_1	α_n	β_1	β_n	m_o	m_n	n	φ'/π
1	--	Normal	4							
2	--	"	3							
3	6	"	7.6	2.2	0	0	72	569	9	.0322
4	7	"	16.0	14.8	0	0	67	552	9	.0336
5	8	"	14.4	13.6	0	0	69	552	9	.0323
6	1	2872	Hit frame No. 15							
7	2	2868	Hit frame No. 15							
8	3	2904	4.0	2.8	0	0	77	517	9	.0319
9	4	2914	16.0	8.0	0	0	67	525	9	.0331
10	5	2888	15.5	Hit frame						
11	9	Low	16	Hit frame No. 15						
12	10	"	11.8	9.3	0	2.4	0	525	7	.0320
13	11	"	13.2	10.6	0	0	0	513	7	.0331
14	12	"	16.0	9.5	0	2.6	0	550	7	.0320
15	13	"	14.3	14.3 ?	0	0	0	180	2	.0334
16	19	Low	10.9	7.0	0	0	0	519	7	.0319
17	15	1218	8.6	5.8	0	0	0	522	7	.0311
18	16	1183	6.0	2.9	0	0	0	544	8	.0328
19	17	1184	3.8	3.8	0	1.9	0	535	8	.0330
20	18	1199	11.2	5.1	0	0	0	522	8	.0329

TABLE VI

STABILITY RESULTS

Inert 40 mm Shell Mk.II T/L/
Inert P.D. Fuze T34

Round No.	Air Density (ratio)	Correction factor*	Average Period (ft.)	Cardboard const.	Period without cards	Stability Factor: Without Cards	Stability Factor: At Muzzle	Stability Factor: At $\rho=1$
	ρ	$\frac{\Sigma(\delta/\alpha)^2}{n}$	L_a	c	L_c	s_c	s_o	s_ρ
3	.957	.31	55.22	9.0	52.44	1.537	1.477	1.413
4	.953	.66	53.89	"	47.96	1.594	1.534	1.462
5	.956	.69	53.67	"	47.47	1.710	1.645	1.573
8	.946	.02	48.89	"	48.71	1.706	1.644	1.555
9	.945	.01	50.89	"	50.80	1.531	1.475	1.394
12	.956	.97	75.00	17.9	57.61	1.406	1.334	1.275
13	.956	.77	73.29	"	59.49	1.335	1.269	1.213
14	.958	.87	78.57	"	62.97	1.313	1.243	1.190
15	.960	3.14	90.00	"				
16	.968	.58	74.14	"	63.74	1.312	1.246	1.206
17	.960	.52	74.57	"	65.25	1.317	1.250	1.200
18	.957	.56	68.00	"	57.96	1.381	1.308	1.252
19	.955	.57	66.88	"	56.66	1.400	1.327	1.267
20	.955	.35	65.25	"	58.97	1.356	1.287	1.229

* δ = yaw at cardboard.

α = maximum yaw at cardboard.

n = number of periods.